ECONOMIC LOADING OF UNITS

By: W. E. Rushlow
System Operations Engineer
Electric Engineering Division

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Incremental loading of generating units seems to be a subject which is not readily accepted by a great many operating people. Yet there are many people, particularly on larger systems where the dollar amount is substantial, who have done a great deal of work on the subject, who are convinced it is the thing to do and use incremental loading in day to day operation. True, their systems are bigger and they may have different circumstances but it behooves us to try to understand what is involved and what incremental loading is all about.

It is very difficult to understand how the overall costs may be less if more load is carried on a higher cost unit. Obviously you cannot reduce your costs by adding a higher cost. Let us forget incremental loading for a moment and imagine a bowler with an average of 145 for 20 games, 140 for 25 games and 142 for 30 games. We can get scientific and plot these on a curve which will look like Fig. I.

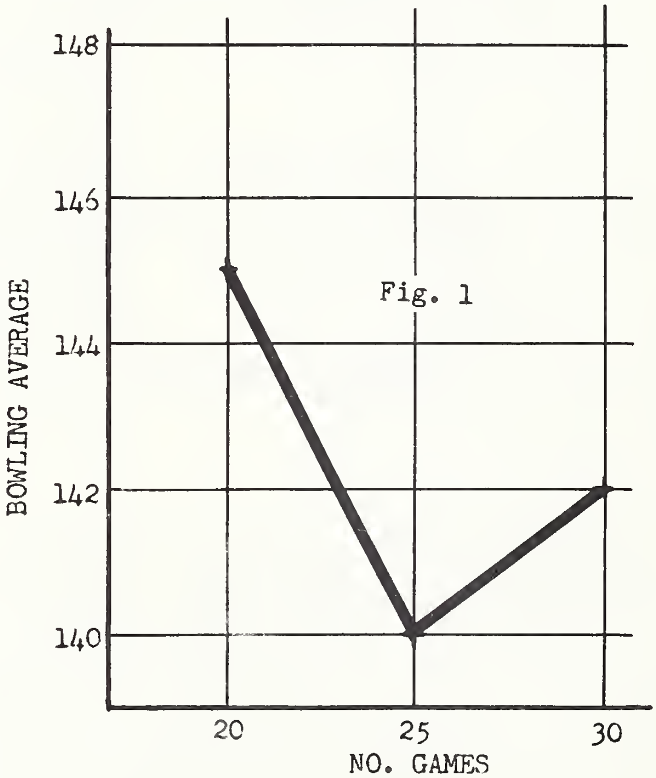


Fig. 1

We all know that any bowler rarely bowls his exact average in any one game and practically always he is above or below his average for the individual game. If we figured out his average after every game we would have more points and the curve would be smoother, however the three points will be sufficient for illustration at the moment as they do indicate whether his average is getting better or worse.

This bowler started with an average of 145 for 20 games and dropped to an average of 140 for 25 games. What then did he bowl for the five games after the 20th?

Averages are determined by dividing the total pinfall by the number of games so if we multiply 25 x 140 and substract 20 x 145 we will get the total pinfall for these five games. By dividing this number by five we will get the average for the five games between the 20th and the 25th. To get scientific again, this would look like the following equation:

$$\frac{(25 \times 140) - (20 \times 145)}{5} = \text{Average for five games}$$

$$\frac{3500 - 2900}{5} = 120$$

The same procedure may be used for finding the average score for the five games between the 25th and the 30th.

$$\frac{(30 \times 142) - (25 \times 140)}{5} =$$

$$\frac{4260 - 3500}{5} = \frac{760}{5} = 152$$

This man started with an average of 145 and the next five games he averaged 120. Although he had overall averages of 145, 140 and 142 he actually bowled 120 for five games and 152 for the next five games. You can say that this bowler has an incremental bowling rate of 120 for the five games between the 20th and the 25th and an incremental bowling rate of 152 for the five games between the 25th and the 30th. We can get real fancy and show this as an incremental bowling rate curve which would look like Fig. 2.

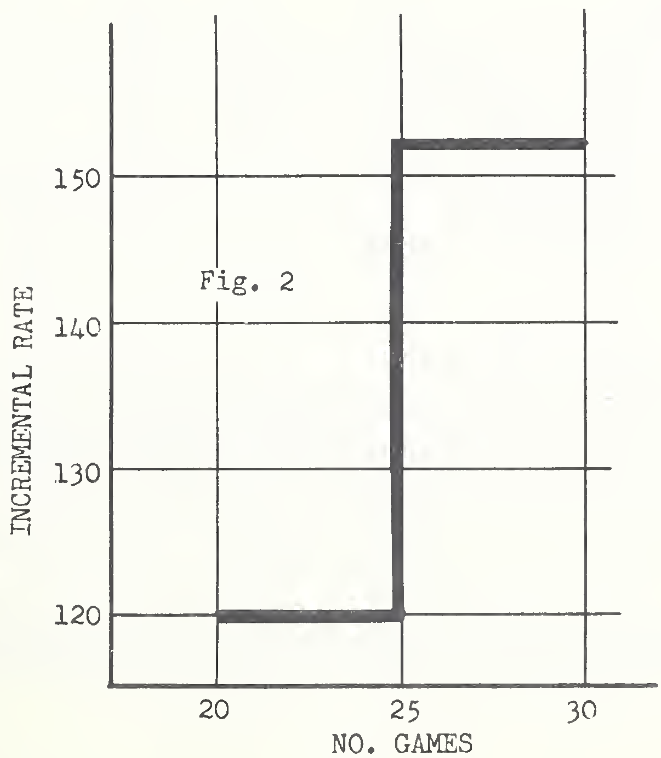
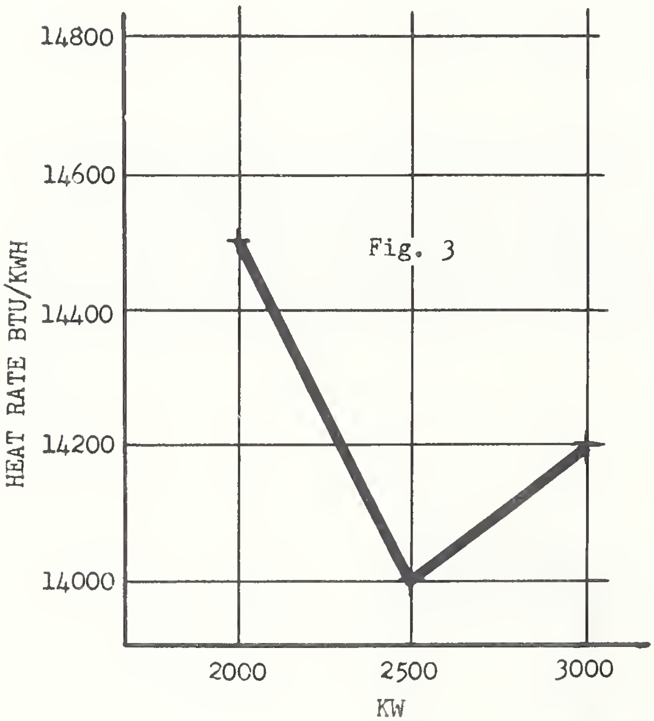
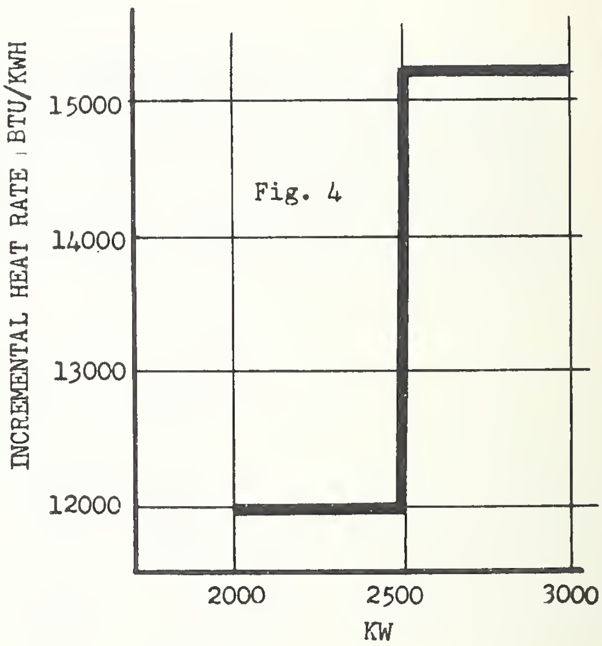


Fig. 2

In figuring incrementals we are not talking about overall averages but what it takes to add to what has happened before. The incremental rate applies ONLY to the little piece you are adding to something else and you cannot make direct comparisons of overall averages with incremental averages. Incremental averages do however affect the overall averages.

To get back to our subject of generating units we may use Fig. 1 and merely change the titles and units of measurement and you will immediately recognize a performance curve as shown in Fig. 3. The incremental rate curve may also be changed the same way as shown in Fig. 4. You will note that at no time does the performance curve show a heat rate greater than 14,500 BTU yet for the 500 kw you are adding to the 2500 kw you must use 15,200 BTU/kwh. On the other hand even though the performance curve shows the lowest heat rate to be 14,000 BTU/kwh you are only using 12,000 BTU/kwh for the portion between 2000 and 2500 kw.



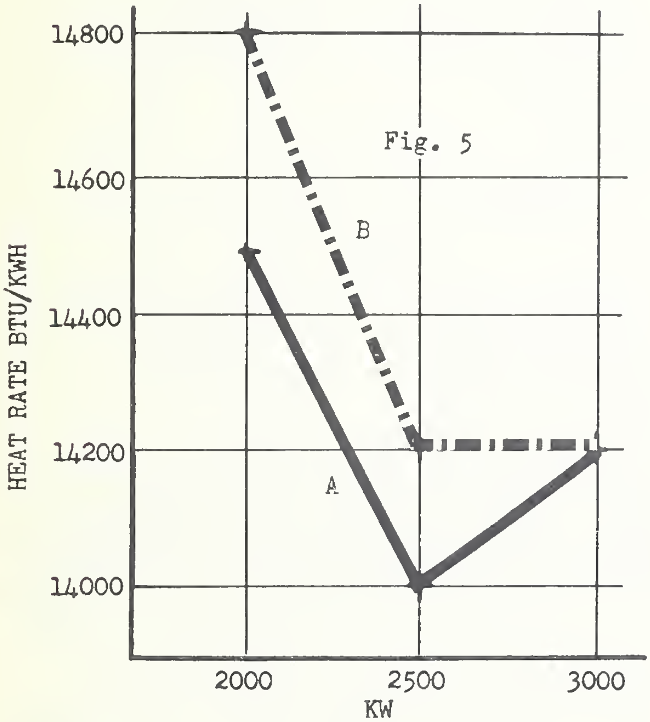


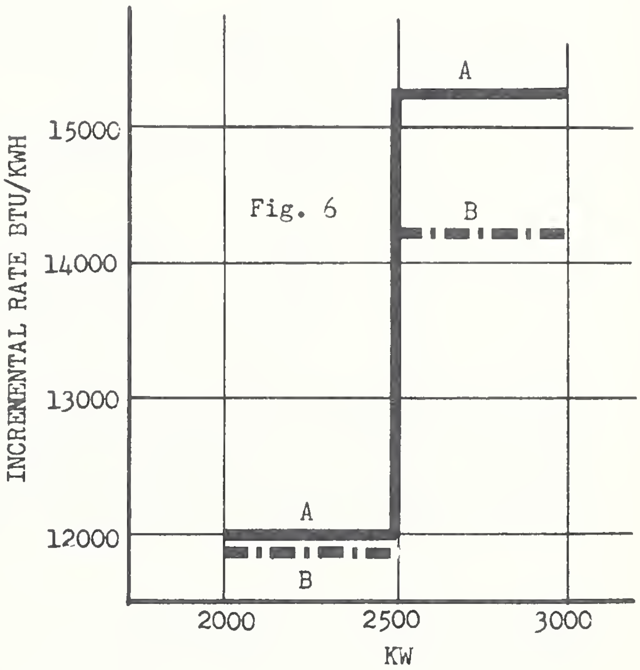
Assume we have a second and less efficient machine (B) with performance characteristics of 14,800 BTU/kwh at 2000 kw; 14,200 BTU/kwh at 2500 kw and 14,200 BTU/kwh at 3000 kw, Plotting these points on Fig. 3, the performance curves for both A & B would look like Fig. 5. Figuring the incremental heat rate curves;

$$\frac{(2500 \times 14{,}200) - (2000 \times 14{,}800)}{500} = 11{,}800 \text{ BTU/kwh}$$

$$\frac{(2500 \times 14{,}200) - (3000 \times 14{,}200)}{500} = 14{,}200 \text{ BTU/kwh}$$

These incremental heat rates plotted on Fig. 4 would combine as machines A & B in Fig. 6.





In Fig. 6 Machine B, although a less efficient machine than A, has a lower incremental heat rate. Therefore if both machines are running, increases should be taken on the machine having the lower incremental heat rate. This would mean that with both machines running at 2000 kw the increases in loads between 4000 and 4500 kw should be taken on B because it would cost only 11,800 BTU/KWH. Between 4500 and 5000 kw increases should be taken on A because it costs 12,000 BTU/KWH. Between 5000 and 5500 kw increases should be taken on B at 14,200 BTU/KWH and the last 500 kw taken on A because it costs 15,200 BTU/KWH.

Looking back at our performance curves on Fig. 5, we are definitely saying for loads between 4000 to 4500 kw and 5000 to 5500 kw, you should keep the most efficient machine lightly loaded and take the load on the less efficient machine. This is beginning to sound like double talk and although figures don't lie, liars may figure. However, let us again forget incremental loading and work from our performance curves only. We have said the lowest cost will result by taking increases on machine B for loads between 4000 to 4500 kw and 5000 to 5500 kw.

For the sake of argument, let us take as much load as possible on the most efficient unit and as little load as possible on the least efficient unit. Under these circumstances we would use the total BTU shown in the following table:

System Load	Load on A	Load on B	Total BTU
4500	2500 x 14,000	2000 x 14,800	64,600,000
5000	3000 x 14,200	2000 x 14,800	72,200,000
5500	3000 x 14,200	2500 x 14,200	78,100,000

The BTU used with incremental loading is as follows:

System Load	Load on A	Load on B	Total BTU
4500	2000 x 14,500	2500 x 14,200	64,500,000
5000	2500 x 14,000	2500 x 14,200	70,500,000
5500	2500 x 14,000	3000 x 14,200	77,600,000

In each instance the total BTU is lower for the incremental loading method. No other combination will give you a lower cost and if you want to prove it go back to the performance curves and figure it out in total BTU. You will find that once you have the incremental loading curves you simply load the unit with the lowest rate, the next lowest, etc. Incremental loading then is merely a tool, worked out on a minimum basis, for using your performance curves.

For those of you who have identical units and assuming they have identical characteristics, incremental loading curves will also tell you how to load the units. Dividing the load equally between units for all loads does not result in the lowest cost. Referring again to Fig. 3 and 4, assume you have two units with the same performance and incremental heat rate curves. For a system load of 5400 kw, putting 2700 kw on each machine, will cost more than 2500 on one and 2900 on the other. Everyone who has more capacity than required to meet the load has something to gain by knowing about and using incremental loading. It is merely a question of how much you gain.

It must be emphasized however that incremental loading applies only to machines that are on the line and only to two or more machines. Referring to Fig. 5, if the system load was less than 3000 kw you would meet this load by using unit A. No combination of A and B together will result in lower costs than A alone, for loads below 3000 kw.

As a matter of convenience you may work up plant loading curves for your system load up to the total installed capacity of your generating units. Such a curve is taken from the incremental load curves and performance curves and looks like Fig. 7. This curve is incomplete for loads between 3000 and 4000 kw because of lack of performance date.

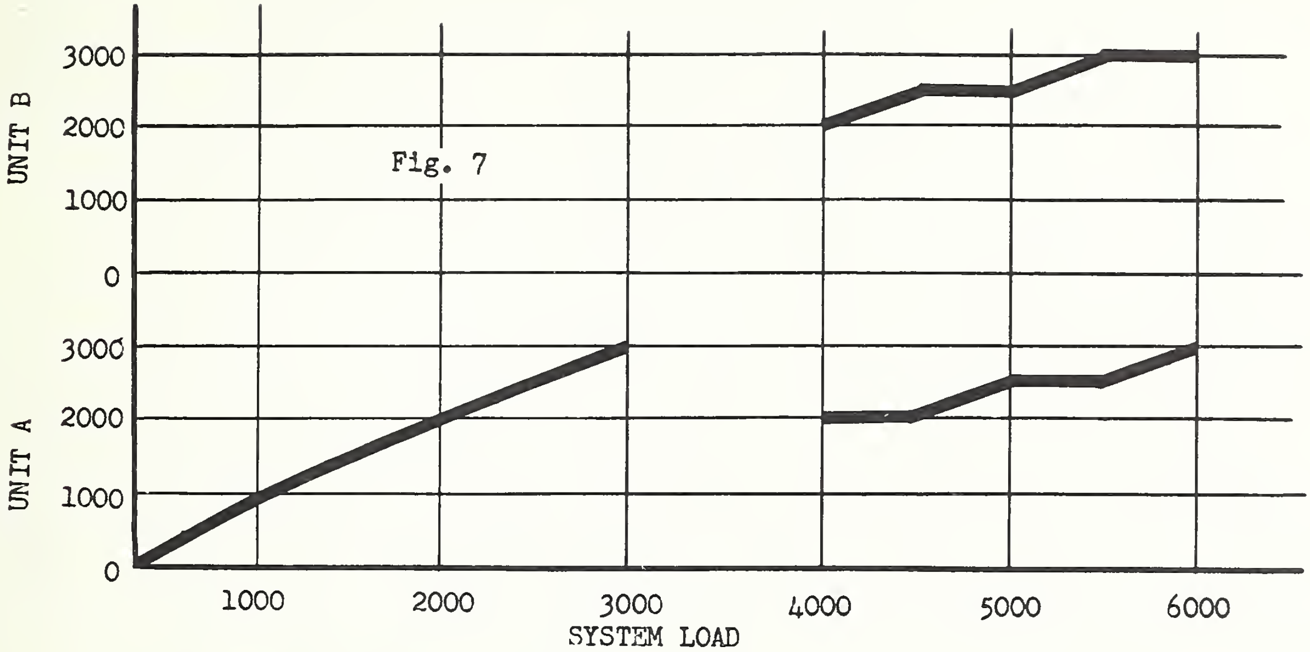


Fig. 7

This explanation is admittedly very rough and was intended to set forth the procedure and mathematical manipulations necessary for incremental loading. It does outline the basis steps which are necessary and if you are convinced incremental loading is worthwhile, knocking off the rough edges is a detail which can be worked out without much difficulty.